U.S. Fish & Wildlife Service

Ecological Services
Anchorage Field Office

Rept. #1 of 2

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Technical Report WAES-TR-98-02

Habitat Conservation

Contaminants Survey: Island Bay Barrel Cache

Alaska Peninsula / Becharof National Wildlife Refuge

Endangered Species

by:
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Environmental Contaminants

July 1998

Acknowledgments

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Executive Summary

In 1988, the U.S. Fish and Wildlife Service (Service) funded a contaminants project with the following objectives : 1) conduct a reconnaisance-level field inspection of selected, abandoned oil well sites on the Alaska Peninsula and the Becharof National Wildlife Refuge, 2) identify and map abandoned physical remains of oil exploration activities, and 3) collect soil samples for organochlorine, petroleum, and metals analysis.

During the project field survey, several sites warranting further study were identified. One site was a cache of 55-gallon drums found near the mouth of Jute Creek, which flows into Island Bay. The drums were located near an old beach landing area and an access road which parallels Jute Creek.

In early 1990, Refuge Manager Ronald Hood proposed to Exxon officials involved in the *Exxon Valdez* oil spill cleanup that Exxon remove the Island Bay barrel cache and other physical remains of exploration left in the area. A background investigation conducted by Exxon revealed that the barrel cache was not part of past Humble (Exxon) operations. Further investigation identified Mobil as the responsible party. General Petroleum Corporation, a subsidiary of Socony/Mobil (now Mobil), had built a dock and the road to conduct additional oil exploration in the area in the late 1950's. Mobil agreed to remove the barrel cache (USFWS, 1992) and the cleanup occurred in June, 1992. While the barrels were being removed, Service personnel sampled soil and groundwater from the area under and around the site to determine if there was any residual contamination.

A petroleum seep nearby on the banks of Jute Creek was also investigated. It may indicate fuel spillage from equipment refueling during cleanup operations associated with the *Exxon Valdez* spill.

Results of the sampling indicate elevated levels of hydrocarbons. Traces of PCBs and other organochlorines were also found. It is recommended that the sites be investigated further to determine the extent of the contamination and the ecological risk associated with them.

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Introduction

History and Purpose of the Refuge

Becharof National Wildlife Refuge, located on the Alaska Peninsula in southwestern Alaska (Map1), was created by the Alaska National Interest Lands Conservation Act of 1980 (ANILCA). The purposes of the refuge as described in Section 302(2)(B) of ANILCA include:

(1) to conserve fish and wildlife populations and habitats in their natural diversity including, but not limited to, brown bears, salmon, migratory birds, the Alaska Peninsula caribou herd and marine birds and mammals;

(2) to fulfill the international treaty obligations of the United States with respect to fish, wildlife, and their habitats;

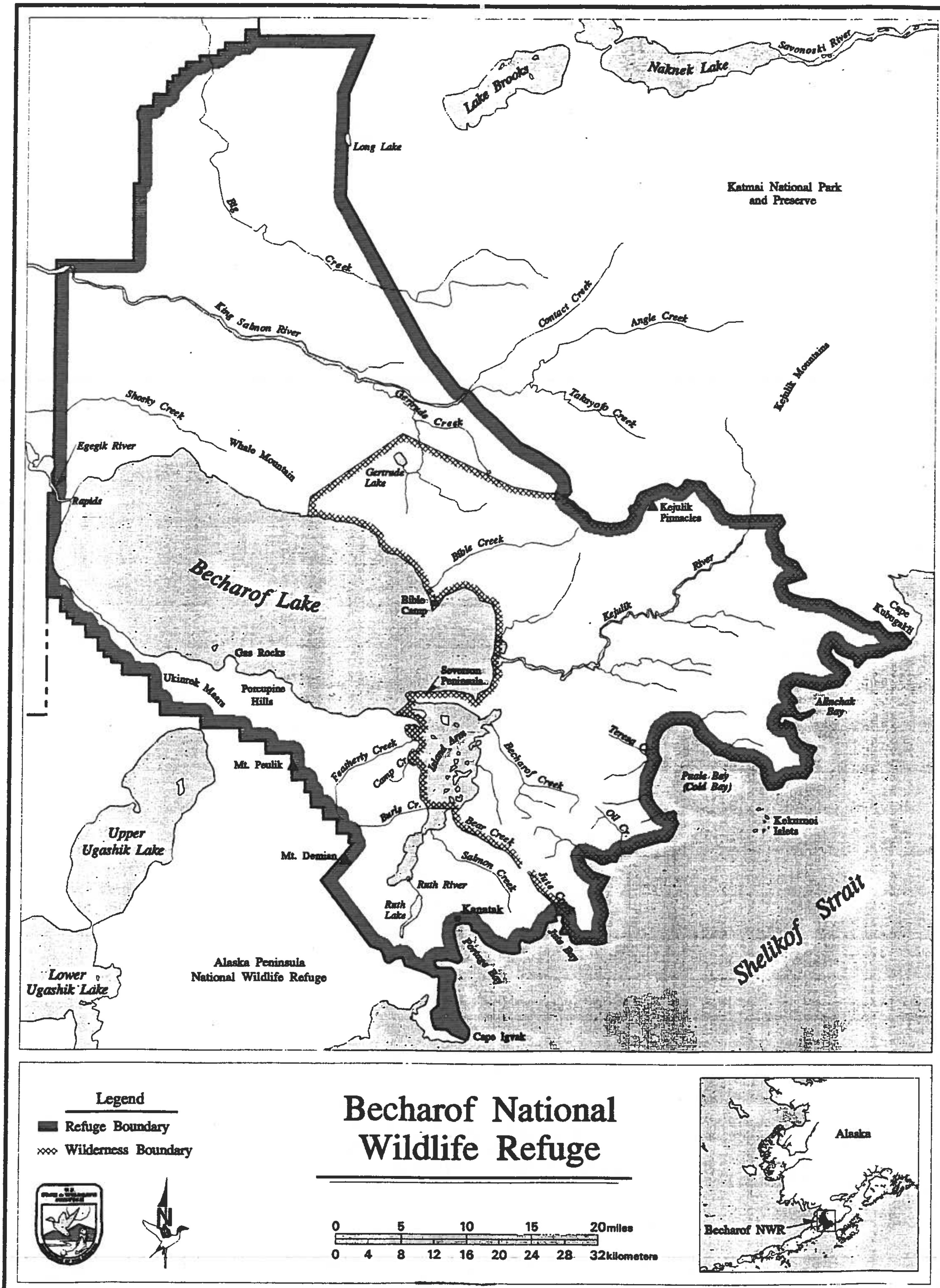
(3) to provide, in a manner consistent with the purposes set forth in subparagraphs (1) and (2), the opportunity for continued subsistence uses by local residents; (and)

(4) to ensure, to the maximum extent practicable and in a manner consistent with the purposes set forth in subparagraph (1), water quality and necessary water quantity within the refuge (USFWS, 1985).

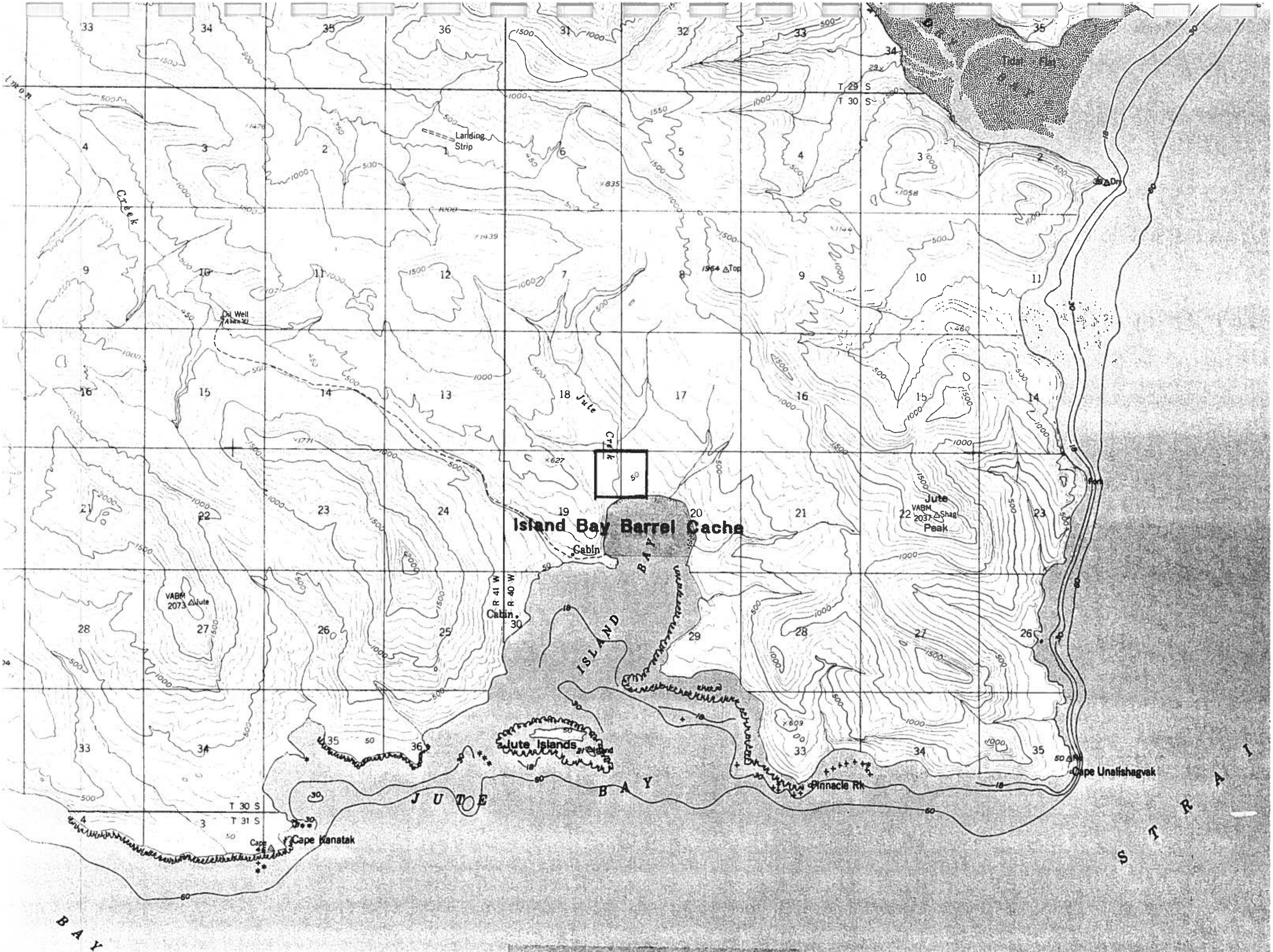
Study Area

Jute Creek and Island Bay are located on the Shelikof Straits-side of the Alaska Peninsula. Jute Creek, which is part of the refuge's southwest wilderness boundary (Map 1), is about two miles long, flows to the southeast and empties into Island Bay, which is an inner bay of Jute Bay (Map 2) on Shelikof Strait.

Jute Creek provides habitat for large numbers of coho (*Oncorhynchus kisutch*) fry (Hood, 1994). Pink *(Oncorhynchus gorbuscha)*and chum (*Oncorhynchus keta*) salmon also utilize Jute Creek for spawning. Brown bears (*Ursus arctos*) depend on the creek for these food sources. Jute Island, at the mouth of Island Bay, provides nesting habitat for hundreds of burrowing tufted puffins (*Fratercula cirrhata*) and, in 1989, an abandoned bald eagle (*Haliaeetus leucocephalus alascenis*) nest was also recorded on the island. An active eagle nest was located near Pinnacle


Becharof National Wildlife Refuge
Legend
Refuge Boundary
Wilderness Boundary
0 5 10 15 20 miles
0 4 8 12 16 20 24 28 32 kilometers
Alaska
Becharof NWR
Lake Brooks
Naknek Lake
Savonoski River
Long Lake
Katmai National Park and Preserve
Big Creek
King Salmon River
Contact Creek
Angle Creek
Kejulik Mountains
Gertrude Creek
Takayofo Creek
Shosky Creek
Whale Mountain
Egegik River
Gertrude Lake
Rapids
Kejulik Pinnacles
Bible Creek
Becharof Lake
Bible Camp
Kejulik River
Cape Kubugakli
Gas Rocks
Severson Peninsula
Ukinrek Maars
Porcupine Hills
Island Arm
Featherly Creek
Camp Cr.
Becharof Creek
Mt. Peulik
Puale Bay (Cold Bay)
Kekurnoi Islets
Upper Ugashik Lake
Oil Cr.
Bear Creek
Mt. Demian
Salmon Creek
Ruth River
Ruth Lake
Kanatak
Jute Bay
Shelikof Strait
Alaska Peninsula National Wildlife Refuge
Lower Ugashik Lake
Cape Igvak

Map 1



Map 2 Study Site Location

Point on the mainland to the east (Dewhurst, 1990). Other species that have been observed in the area include: horned puffins (*Fratercula corniculata*), harlequin ducks (*Histrionicus histrionicus*), surf scoters (*Malanitta perspicillata*), black scoters (*Mellanitta nigra americana*), black turnstones (*Arenaria melanocephala)*, rock sandpipers (*Calidris ptilocnemis*), various surfbirds, semipalmated plovers (*Charadrius semipalmatus*), glaucous-winged gulls (*Larus glaucescens*), water pipits (*Anthus spinoletta*), various swallows, red fox (*Vulpes fulva*), and harbor seals (*Phoca vitulina*) (USFWS, 1990).

History of Petroleum Exploration in the Study Area

From 1957 to 1959, a consortium of oil companies composed of the Humble Oil and Refining Company (Humble), now part of Exxon, and the General Petroleum Corporation (now Mobil Oil) conducted an oil and gas exploration program on what is now the Becharof National Wildlife Refuge. A docking installation, which was utilized by both Humble and General Petroleum, was constructed at Island Bay and an access road was built by Humble from Island Bay to service the Bear Creek exploration well near the headwaters of Jute Creek. This exploration well was abandoned in 1959. General Petroleum continued their exploratory program further inland through 1959 but found no commercial quantities of oil and gas. The exploration program was abandoned by 1960. Demobilization was accomplished by General Petroleum through the Bear Creek/Island Bay area.

Study Background

Overflights of the refuge in the 1980s revealed a number of sites where debris from abandoned exploration sites remained. Several sites were visited, including the Island Bay site. Remains of the support facilities and a half-buried cache of drums were found on the banks of Jute Creek where it meets Island Bay. No sampling of the barrels or the immediate area was done at that time.

The refuge, coordinating with the Bureau of Land Management as the regulator of subsurface leasing for oil and gas on federal lands, began requesting Mobil (as the last user of the Island Bay staging area) to submit cleanup plans for the area. Initially Exxon was also asked to remove the Jute Creek barrel cache but they declined since they were convinced that they were not responsible. This assumption rested on the fact that the Department of Interior sent a letter to Exxon in 1960 which stated that "the site was found to be satisfactorily cleaned up at the time of abandonment." It is impossible to know whether the letter refers to the Bear Creek well site, approximately four miles away, or the Island Bay docking faciltity.

In 1992 Mobil offered under the "Take Pride in America" campaign (a U.S. Fish and Wildlife Service initiative to remove debris abandoned on refuges) to remove the barrel cache and miscellaneous metal trash at Island Bay. The cleanup was subcontracted to Northern Exploration Services, who performed the work in 1992.

Potential Impacts from Oil and Gas Exploration

Oil and gas exploration has the potential to contaminate the environment with a variety of chemical compounds. The most probable contaminants are the refined petroleum products utilized to power vehicles and equipment. However, other contaminants such as crude oil, metals and halogenated (ie. chlorinated) compounds may be present due to their use in well drilling and site operations (e.g., drilling mud, batteries for machinery and auxiliary power, maintenance shops, etc.).

Petroleum

Crude oil and refined petroleum products are made up of a complex mixture of chemical compounds. Even when the toxicity of individual compounds is known, it is difficult to determine what the toxic effect of these mixtures will be in the environment due to the additive, synergistic, or antagonistic effects of the various compounds. In addition, crude oil and refined petroleum products can have diverse effects on organisms within the same ecosystem (Overton, et. al., 1994).

The light-end fractions of petroleum hydrocarbons (C6-C10) consisting primarily of benzene, toluene, ethylbenzene and xylenes (BTEX) and napthalene are the most toxic and abundant compounds present during the initial stages of spills or releases. It is in these early stages of a spill that acute toxic effects are most common. As petroleum weathers, these singlering, lower molecular weight compounds, being more volatile, soluble, and/or biodegradable, are lost, leaving behind the less acutely toxic, multi-ring, higher molecular weight compounds known as polycyclic aromatic hydrocarbons (PAHs) (Overton, et. al., 1994).

PAHs are persistent in the environment and have the potential to create chronic toxicity problems. Polycyclic aromatic hydrocarbons are known inducers of cancerous and precancerous lesions (Eisler, 1987), and at least one known human carcinogen, benzo(a)pyrene, has also been identified as a mutagen (Overton, et. al., 1994).

Petroleum products also contain trace amounts of metals including aluminum, nickel, chromium, lead, vanadium and zinc. Although some of these metals are required as essential micronutrients by living systems, they may also become toxic to living systems at relatively low levels of exposure.

Other Contaminants

Halogenated aromatic compounds, such as polychlorinated biphenyls (PCBs), and organochlorine (OCs) compounds, may also be present at older exploration sites. PCBs and a number of OCs (eg. DDT) are no longer manufactured for use in the U.S. but, due to their earlier widespread use and resistance to degradation, they are still found in the environment.

PCBs are closely related to pesticides in their chemical, physical, and toxicological properties. Unlike pesticides, they were never intended to become part of the environment. Most were used in "closed" systems such as electrical transformers and capacitors. PCBs were also used as lubricants, fluids in vacuum pumps and compressors, and in heat transfer and hydraulic fluids. PCBs are mixtures of various isomers and are identified most commonly under the trade name "Aroclor" on the basis of the percent chlorine present. For example, Aroclor 1254, is a mixture of isomers with an average chlorine content of 54 percent by weight. Since there are 209 PCB isomers, and these isomers differ in physical, chemical, and biological properties, evaluation of the potential environmental impacts from a particular PCB product is complicated. PCBs also biomagnify in food chains; and since the late 1960's, they have been linked increasingly to adverse reproductive effects and developmental deficits in a variety of fish-eating birds and mammals (Eisler, 1986).

In some parts of the world, OC-containing pesticides may have been used around exploration sites to reduce disease-carrying insects. The properties that make OCs effective pesticides (low volatility, chemical stability, lipid solubility, slow rates of biotransformation and degradation) also make them a problem for wildlife and humans. Pesticide persistence in the environment and their ability to bioconcentrate and biomagnify within various food chains can result in significant body burdens in some species. In certain cases, such body burdens have been found to be detrimental to reproductive success and even lethal to many species (Ecobichon, 1991).

Objective

The objective of the Island Bay barrel cache survey was to perform post-cleanup sampling of this site in order to determine if contaminants were present at levels that could pose a threat to fish and wildlife on the Refuge.

Site Location

The Island Bay barrel cache is located next to the mouth of Jute Creek adjacent to the wilderness boundary of the Becharof National Wildlife Refuge: Section 20, Township 30 South, Range 40 West, Karluk (C6) Quadrangle (Map 2). The barrels were stacked on timbers and half buried in a foredune area bracketed by an estuary to the northwest and Island Bay to the southeast. The present shoreline is approximately two hundred feet from the site. The soils are unconsolidated beach deposits with a shallow water table under tidal influence. The vegetation includes a few grasses and shrubs.

Methods and Materials

Field Procedures

There were approximately 1500 barrels, many of them labelled as petroleum products, divided into two stacks in the Island Bay barrel cache (see Appendix A for a schematic drawing). Approximately 50 of the barrels contained some residues which were composited into new barrels and removed from the site along with the empty, crushed barrels.

Those containing residues raised concerns that petroleum hydrocarbons may have leaked into groundwater either prior to or during the removal of the barrels. After all the barrels had been removed, one pit each (Pits 1 and 2) was dug in the center of the areas where the two barrel stacks had been located. A hydrocarbon sheen collected on the surface of the groundwater, approximately two feet below ground surface. With visual evidence of contamination, a sampling design was formulated on-site to delineate the impacted area. A total of 12 more pits were excavated and sampled.

In pits 3, 4, and 5, dug between the barrel cache and the estuary, there was no physical evidence of petroleum hydrocarbons at the groundwater table. Pit 6, dug between the barrel cache and Jute Creek to determine if ground water flow was carrying hydrocarbons to the creek, appeared clean. Pit 7, also dug between the cache and creek but farther east, showed a trace of sheen. In pits 8, 9, 10, and 11 which were dug in or near the barrel cache, a light petroleum hydrocarbon sheen was present at the groundwater table. Pits 12, 13 and 14, well removed from the cache, were dug specifically to investigate a petroleum hydrocarbon seep that was evident along the bank of Jute Creek at the edge of the foredune. Pits 12 and 13 were dug beginning where the road crosses the creek and leads to the beach landing area. Although there was no visual sign of contamination on the surface, these pits had a strong hydrocarbon odor and the sand and gravel in them from just below the surface to approximately six feet down was gray and greasy. This apparently was the source of the petroleum seep found further down the beach. Pit 14, dug farthest south, was clean.

The 14 pits were designated and sampled from "clean" to "dirty" based on the visual evidence of petroleum. Two soil samples and one groundwater sample were collected at the groundwater table from each pit, except for pits 13 and 14, from which only two soil samples were collected. In all, 28 soil and 12 groundwater samples were collected for aliphatic hydrocarbons (AH), PAH, and OC analyses.

Samples were collected in pre-cleaned I-Chem 300 Series glass jars which were also used as the sampling scoop. No other sampling tools touched the sample. Surgical gloves were worn by the sampler and were changed between pits. The sample jars were labelled immediately after collection. Samples were transported back to the refuge by helicopter within two hours. The water samples were refrigerated and the soil samples frozen. All were transferred in this condition to Anchorage. Water samples were held refrigerated and soil samples held frozen for two months in Service facilities prior to shipment to the laboratory.

Analytical Procedures

Sample analysis was conducted by the Geochemical & Environmental Research Group, Texas A&M.

Organic and pesticide compounds in soil/ sediment samples were extracted in a Soxhlet extraction apparatus; the extracts were then treated with copper to remove sulfur. They were separated by silica/aluminum column chromatography into the AH, PAH, OC, and PCB fractions and analyzed by gas chromatography.

Organic and pesticide compounds in water samples were extracted using methylene chloride and a separation funnel, concentrated, separated using alumina/silica gel chromatography, and the fractions analyzed by gas chromatography.

Quality Assurance / Quality Control (QA/QC) Screening

The raw data collected during this study was reviewed against the following criteria developed by the Environmental Contaminants Group in the Service's Anchorage Field Office. The criteria are extremely conservative compared to the values generally used by the regulatory community [2x practical quantitation limit (PQL)[1] versus 5x as "significant" values]. The intent is to draw attention to the presence of substances which may present a threat to fish and wildlife.

Analytes which meet the following screening criteria are discussed in the report:

1) Analyte concentrations must be at least 2x the PQL.
2) At least 50% of the duplicates for the analyte must have a relative percent difference <20%,
3) At least 50% of the spike recoveries for the analyte must be within the range of 80-120%
4) At least 50% of the test blanks for the analyte must be non detect.

A complete set of raw data is available in the files at the Anchorage Field Office.

Results and Discussion

Appendix B presents the analytical results for the soil samples from the Island Bay barrel cache. Groundwater samples were non-detect for all analytes.

QA/QC

Table 1 lists the analytes that were tested for in soil samples collected from the Island Bay barrel cache site. A number of the analyte values for AHs and PAHs and most of those for OCs were less than 2x the PQL. A few analytes (n-hexadecane, n-nonadecane,n-octacosane, n-octadecane, biphyenl, and dibenzothiophene) were also eliminated because they did not meet spike or duplicate criteria.

Table 2 lists the sum of the PAH values for all the soil samples collected at Island Bay barrel cache which passed the QA/QC criteria.

[1]The practical quantitation limit is the lowest level that can be reliably achieved within specified limits of precision and accuracy during routine laboratory operating conditions.

Table 1. Analytes tested for in soil samples collected June 1992 at the Island Bay barrel cache, Alaska Peninsula/Becharof National Wildlife Refuge.

AH	PAH	OC
n-decane	<2x 1,2,5,6-dibenzanthracene	<2x aldrin
n-docosane	<2x 1,2-benzanthracene	<2x hexachlorobenzene
n-dodecane	1,6,7-trimethyl-naphthalene	<2x heptachlor
n-dotriacontane	C1-fluoranthenes & pyrenes	PCB-total
n-eicosane	C1-phenanthrenes & anthracenes	alpha BHC
n-heneicosane	C1-chrysenes	<2x alpha chlordane
n-hentriacontane	C1-dibenzothiophenes	<2x beta BHC
n-heptacosane	C1-fluorenes	<2x cis-nonachlor
n-heptadecane	C1-naphthalenes	<2x delta BHC
n-hexacosane	C2-phenanthrenes & anthracenes	dieldrin
D n-hexadecane	C2-chrysenes	<2x endrin
n-nonacosane	C2-dibenzothiophenes	gamma BHC
D n-nonadecane	C2-fluorenes	<2x gamma chlordane
S n-octacosane	C2-naphthalenes	<2x heptachlor epoxide
D n-octadecane	C3-phenanthrenes & anthracenes	<2x mirex
n-pentacosane	<2x C3-chrysenes	<2x o,p'-DDD
n-pentadecane	C3-dibenzothiophenes	<2x o,p'-DDE
n-tetracosane	C3-fluorenes	<2x o,p'-DDT
n-tetradecane	C3-naphthalenes	<2x oxychlordane
<2x n-tetratriacontane	C4-phenanthrenes & anthracenes	<2x p,p'-DDD
<2x n-triacontane	<2x C4-chrysenes	p,p'-DDE
n-tricosane	C4-naphthalenes	<2x p,p'-DDT
n-tridecane	acenaphthalene	toxaphene
n-tritriacontane	acenaphthene	<2x trans-nonachlor
n-undecane	anthracene	
phytane	<2x benzo(a)pyrene	
	<2x benzo(b)fluoranthene	
	<2x benzo(e)pyrene	
	<2x benzo(g,h,i)perylene	
	<2x benzo(k)fluoranthene	
	S biphenyl	
	chrysene	
	S dibenzothiophene	
	fluoranthene	
	fluorene	
	<2x indeno(1,2,3-cd)pyrene	
	naphthalene	
	<2x perylene	
	phenanthrene	
	pyrene	

<2x Analyte did not meet quality assurance criteria for detection limits.

D Analyte did not meet quality assurance criteria for duplicates.

S Analyte did not meet quality assurance criteria for spike recoveries.

Table 2. Sum of petroleum hydrocarbon concentrations (ppm dry wt.) in soil samples collected at Island Bay barrel cache, Alaska Peninsula/Becharof National Wildlife Refuge.

Sample	Aliphatics	Aromatics	Unresolved Complex Mixture	Total
1	2.952	1.542	29.787	34.281
2	2.484	1.601	24.802	28.887
4	1.748	1.092	15.536	18.376
5	3.005	1.903	25.096	30.004
7	2.763	1.043	25.711	29.517
8	2.755	1.295	26.092	30.142
10	3.622	1.398	32.845	37.865
11	1.609	0.578	12.390	14.577
13	3.609	1.351	33.532	38.492
14	2.469	0.988	18.804	22.261
16	1.517	0.721	14.211	16.449
17	2.666	1.367	22.319	26.352
19	11.288	4.701	44.236	60.225
20	3.252	1.267	21.244	25.763
22	3.680	1.384	34.316	39.380
23	2.666	0.870	23.803	27.339
25	3.985	1.665	36.544	42.194
26	1.903	1.473	15.334	18.710
28	4.537	1.506	40.704	46.747
29	0.439	0.186	8.333	8.958
31	3.687	2.352	30.082	36.121
32	3.532	1.269	29.103	33.904
34	73.080	16.471	407.263	496.814
35	16.601	7.231	95.762	119.594
37	23.399	21.455	98.725	143.579
38	19.752	29.770	73.557	123.079
39	125.845	273.083	480.444	879.372
40	16.282	233.438	56.439	306.159

Organochlorines

Organochlorines were detected in Pit 2 (samples 34, 35), Pit 12 (samples 37, 38), and Pit 13 (samples 39, 40) (see Appendix B3). Concentrations of PCBs (total) were found in all these samples; however, the concentrations are very low (0.028 - 0.104 ppm dry wt.). Sample 39 contained alpha BHC (0.067 ppm dry wt.), dieldrin (0.044 ppm dry wt.), p, p'-DDE (0.023 ppm dry wt.), and toxaphene (0.044 ppm dry wt.). Gamma BHC at 0.028 ppm dry wt. and toxaphene at 0.084 ppm dry wt. was measured in sample 34 and 0.053 ppm dry wt. of toxaphene were measured in sample 35.

Petroleum Hydrocarbons

Table 2 presents the concentrations of aliphatic, aromatic, and unresolved complex mixtures (hydrocarbon fractions which could not be specifically identified) found in the soil samples. The sum of these compounds for each sample are presented as an estimate of TPH. The assumption is that the true value for TPH would be much higher. The samples from the barrel cache area contained levels generally ranging from approximately 9 to 60 ppm dry wt. of PAHs. Samples 34 - 40 from the barrel cache and from the heavily stained soils close to the creek were significantly higher, containing concentrations ranging from 123 to 879 ppm dry wt.

Samples 34 and 35, taken from Pit 2 in the barrel cache area, indicate that the barrels probably contained petroleum residues and organochlorines which leaked to groundwater. Samples 37 - 40, taken from pits 12 and 13 adjacent to the mouth of Jute Creek where it enters Island Bay, also show elevated levels of petroleum combined with traces of organochlorines. The assumption is made that this is evidence of a spill associated with equipment refueling operations during the *Exxon Valdez* cleanup, particularly when the site is specifically referenced as the only 1990 Exxon helicopter fuel cache in the area (Dewhurst, et al., 1990).

Recommendations

Analysis of the soil samples taken from the barrel cache area and from the assumed spill site at the mouth of Jute Creek indicates that there is some level of PAHs present in all the samples, ranging from a low of 8.958 to 879.372 ppm. Whether these PAHs are normal background or the result of anthropogenic activities cannot be confirmed lacking a control site. However, all physical evidence, plus the presence of organochlorines such as PCBs, alpha and gamma BHC, dieldrin, p,p'DDE, and toxaphene, indicates a strong possibility that petroleum products and other materials have been spilled.

The Service is concerned that these contaminants are already entering ground water, as evidenced by the sheening observed in the sample pits at the barrel cache, and that the apparent spill site at the mouth of Jute Creek is in close proximity to both fresh surface water and the marine environment. It is recommended that the significance of these levels to the fish and wildlife resources in the area be determined through further investigation of the nature and extent of contamination.

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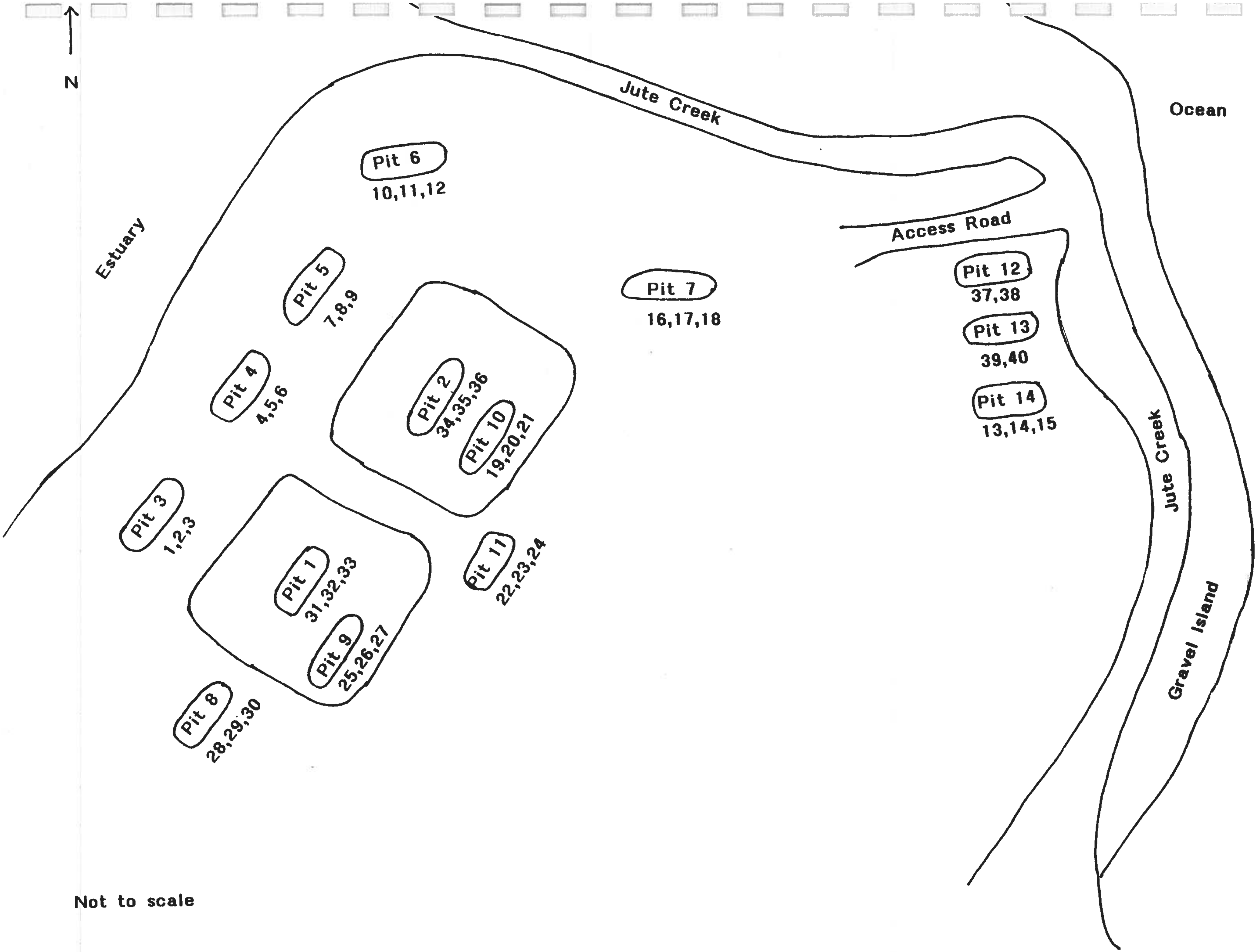
Appendix A

Island Bay Barrel Cache Sampling Sites



N
Ocean
Jute Creek
Estuary
Access Road
Gravel Island
Jute Creek
Pit 6
10,11,12
Pit 5
7,8,9
Pit 4
4,5,6
Pit 3
1,2,3
Pit 7
16,17,18
Pit 2
34,35,36
Pit 10
19,20,21
Pit 1
31,32,33
Pit 9
25,26,27
Pit 8
28,29,30
Pit 11
22,23,24
Pit 12
37,38
Pit 13
39,40
Pit 14
13,14,15
Not to scale

Appendix B

Contaminants data from the Island Bay Barrel Cache

Concentrations (ppm dry weight)

(-) indicates a concentration <2x the detection limit

B1. Aliphatic Hydrocarbons

AH	Sample #						
	1	2	4	5	7	8	10
n-decane	-	-	0.021	0.033	0.020	-	0.021
n-docosane	-	-	-	-	-	-	-
n-dodecane	0.181	0.135	0.109	0.177	0.222	0.176	0.189
n-dotriacontane	-	-	-	-	-	-	-
n-eicosane	0.020	-	-	0.023	-	-	0.021
n-heneicosane	-	-	-	-	-	-	-
n-hentriacontane	-	-	-	0.020	0.036	0.021	0.021
n-heptacosane	0.029	0.025	0.025	0.040	0.040	0.036	0.034
n-heptadecane	0.043	0.041	0.037	0.061	0.041	0.039	0.062
n-hexacosane	-	-	-	-	-	-	-
n-nonacosane	-	-	-	0.029	0.042	0.029	0.028
n-pentacosane	0.024	0.021	0.022	0.032	0.030	0.026	0.028
n-pentadecane	0.558	0.495	0.322	0.598	0.439	0.481	0.733
n-tetracosane	0.021	0.024	-	0.023	0.021	0.020	0.028
n-tetradecane	1.210	1.004	0.678	1.085	0.984	1.047	1.393
n-tricosane	-	-	-	0.024	0.021	-	0.020
n-tridecane	0.796	0.685	0.486	0.767	0.802	0.826	0.962
n-tritriacontane	-	-	-	-	-	-	-
n-undecane	0.036	0.024	0.027	0.047	0.037	0.027	0.033
phytane	0.034	0.030	0.021	0.046	0.028	0.027	0.049
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Total	2.952	2.484	1.748	3.005	2.763	2.755	3.622

AH	Sample #						
	11	13	14	16	17	19	20
n-decane	0.019	-	-	-	-	-	-
n-docosane	-	-	-	-	-	0.240	0.056
n-dodecane	0.130	0.172	0.118	-	0.173	0.402	0.199
n-dotriacontane	-	-	-	-	-	-	-
n-eicosane	-	-	-	-	-	0.729	-
n-heneicosane	-	-	-	-	-	0.476	-
n-hentriacontane	-	-	0.146	0.025	0.029	0.050	0.043
n-heptacosane	0.034	0.020	0.047	0.025	0.037	0.025	0.025
n-heptadecane	0.031	0.053	0.029	0.028	0.035	1.556	0.341
n-hexacosane	-	-	-	-	-	-	-
n-nonacosane	0.025	0.019	0.121	0.027	0.035	1.000	0.040
n-pentacosane	0.029	-	0.025	-	0.027	0.040	0.021
n-pentadecane	0.267	0.772	0.410	0.323	0.445	2.145	0.662
n-tetracosane	0.021	-	-	-	0.020	0.072	0.030
n-tetradecane	0.547	1.517	0.923	0.629	1.034	2.279	0.978
n-tricosane	0.019	-	-	-	-	0.118	0.032
n-tridecane	0.441	1.018	0.610	0.439	0.784	1.334	0.628
n-tritriacontane	-	-	0.040	-	-	-	-
n-undecane	0.025	-	-	-	0.025	0.051	0.034
phytane	0.021	0.038	-	0.021	0.022	0.771	0.163
	-----	-----	-----	-----	-----	-----	-----
Total	1.609	3.609	2.469	1.517	2.666	11.288	3.252

B1. Aliphatic Hydrocarbons cont...

AH	Sample #						
	22	23	25	26	28	29	31
n-decane	-	-	-	-	-	0.078	-
n-docosane	-	-	-	-	-	-	-
n-dodecane	0.182	0.142	0.144	0.083	0.199	-	0.254
n-dotriacontane	-	-	-	-	-	-	-
n-eicosane	0.028	-	0.021	-	0.023	0.028	0.028
n-heneicosane	0.020	-	-	-	-	0.034	0.018
n-hentriacontane	0.032	0.023	0.023	0.033	0.107	-	-
n-heptacosane	0.032	0.025	0.024	0.029	0.055	0.021	0.024
n-heptadecane	0.067	0.037	0.074	0.028	-	0.049	0.072
n-hexacosane	-	-	-	-	-	-	-
n-nonacosane	0.034	0.023	0.023	0.037	0.106	-	0.021
n-pentacosane	0.025	0.020	0.020	0.025	0.031	0.023	0.025
n-pentadecane	0.782	0.468	0.860	0.343	0.924	0.039	0.662
n-tetracosane	0.028	0.020	0.020	-	0.023	-	0.021
n-tetradecane	1.466	1.115	1.697	0.830	1.782	0.025	1.391
n-tricosane	-	-	-	-	0.021	-	-
n-tridecane	0.905	0.772	1.024	0.495	1.182	-	1.096
n-tritriacontane	-	-	-	-	0.030	-	-
n-undecane	0.024	-	-	-	-	0.056	0.027
phytane	0.055	0.021	0.055	-	0.054	0.086	0.048
	-----	-----	-----	-----	-----	-----	-----
Total	3.680	2.666	3.985	1.903	4.537	0.439	3.687

AH	Sample #						
	32	34	35	37	38	39	40
n-decane	-	-	-	-	-	0.024	-
n-docosane	-	2.352	0.567	0.483	0.355	3.326	0.405
n-dodecane	0.167	0.244	0.077	0.379	0.324	0.966	0.140
n-dotriacontane	-	0.021	-	-	-	-	-
n-eicosane	0.021	7.233	1.657	1.703	1.308	10.319	1.390
n-heneicosane	-	4.585	1.101	0.980	0.729	6.260	0.814
n-hentriacontane	-	0.194	0.020	-	-	-	-
n-heptacosane	0.021	0.109	0.015	-	-	0.111	-
n-heptadecane	0.087	15.054	3.580	4.852	4.016	28.576	3.633
n-hexacosane	-	0.151	0.057	0.022	0.020	0.214	0.019
n-nonacosane	0.019	0.151	0.021	-	-	0.031	-
n-pentacosane	-	0.280	0.066	0.067	0.050	0.428	0.050
n-pentadecane	0.733	17.641	4.041	5.355	4.831	30.912	3.837
n-tetracosane	0.023	0.550	0.119	0.122	0.088	0.749	0.088
n-tetradecane	1.506	11.531	2.485	4.621	3.993	23.697	2.907
n-tricosane	-	1.078	0.260	0.241	0.174	1.512	0.185
n-tridecane	0.894	2.774	0.640	2.218	2.106	6.970	1.217
n-tritriacontane	-	0.043	-	-	-	-	-
n-undecane	0.021	-	-	-	-	0.021	-
phytane	0.040	9.089	1.895	2.356	1.758	11.729	1.597
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Total	3.532	73.080	16.601	23.399	19.752	125.845	16.282

2. Polycyclic Aromatic Hydrocarbons

PAH	Sample #						
	1	2	4	5	7	8	10
1,6,7-trimethyl-naphthalene	0.068	0.075	0.039	0.070	0.031	0.035	0.034
C1-fluoranthenes & pyrenes	-	-	-	-	-	-	-
C1-phenanthrenes & anthracenes	-	-	0.023	0.033	-	-	0.042
C1-chrysenes	-	-	-	-	-	-	-
C1-dibenzothiophenes	-	-	-	-	-	-	-
C1-fluorenes	-	-	-	-	-	-	-
C1-naphthalenes	0.234	0.234	0.211	0.269	0.241	0.298	0.293
C2-phenanthrenes & anthracenes	-	-	-	-	-	-	0.023
C2-chrysenes	-	-	-	-	-	-	-
C2-dibenzothiophenes	-	-	-	-	-	-	-
C2-fluorenes	-	-	-	-	-	-	-
C2-naphthalenes	0.728	0.745	0.497	0.679	0.520	0.660	0.663
C3-phenanthrenes & anthracenes	-	-	-	-	-	-	-
C3-dibenzothiophenes	-	-	-	-	-	-	-
C3-fluorenes	-	-	-	-	-	-	-
C3-naphthalenes	0.403	0.427	0.234	0.387	0.197	0.240	0.244
C4-phenanthrenes & anthracenes	-	-	-	-	-	-	-
C4-naphthalenes	0.109	0.120	0.067	0.132	0.054	0.062	0.071
acenaphthalene	-	-	-	-	-	-	-
acenaphthene	-	-	-	-	-	-	-
anthracene	-	-	-	-	-	-	-
chrysene	-	-	-	-	-	-	-
fluoranthene	-	-	-	-	-	-	-
fluorene	-	-	-	-	-	-	-
naphthalene	-	-	0.021	-	-	-	-
phenanthrene	-	-	-	0.333	-	-	0.028
pyrene	-	-	-	-	-	-	-
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Total	1.542	1.601	1.092	1.903	1.043	1.295	1.398

B.2. Polycyclic Aromatic Hydrocarbons

PAH	Sample #						
	11	13	14	16	17	19	2
1,6,7-trimethyl-naphthalene	-	0.037	0.021	0.019	0.030	0.176	0.04
C1-fluoranthenes & pyrenes	-	-	-	-	-	-	
C1-phenanthrenes & anthracenes	-	-	-	-	0.047	0.365	0.05
C1-chrysenes	-	-	-	-	-	-	
C1-dibenzothiophenes	-	-	-	-	-	0.099	
C1-fluorenes	-	-	-	-	-	0.101	0.02
C1-naphthalenes	0.135	0.276	0.230	0.154	0.303	0.586	0.23
C2-phenanthrenes & anthracenes	-	-	-	-	0.025	0.212	0.03
C2-chrysenes	-	-	-	-	-	-	
C2-dibenzothiophenes	-	-	-	-	-	0.098	
C2-fluorenes	-	-	-	-	-	0.188	0.03
C2-naphthalenes	0.289	0.710	0.506	0.371	0.641	1.188	0.47
C3-phenanthrenes & anthracenes	-	-	-	-	-	0.074	
C3-dibenzothiophenes	-	-	-	-	-	0.038	
C3-fluorenes	-	-	-	-	-	0.146	0.02[illegible]
C3-naphthalenes	0.118	0.260	0.182	0.136	0.228	0.874	0.23[illegible]
4-phenanthrenes & anthracenes	-	-	-	-	-	0.020	-
4-naphthalenes	0.036	0.068	0.049	0.041	0.064	0.323	0.08[illegible]
acenaphthalene	-	-	-	-	-	-	-
cenaphthene	-	-	-	-	-	-	-
nthracene	-	-	-	-	-	-	-
chrysene	-	-	-	-	-	-	-
fluoranthene	-	-	-	-	-	-	-
luorene	-	-	-	-	-	0.038	-
aphthalene	-	-	-	-	-	0.025	-
phenanthrene	-	-	-	-	0.029	0.150	0.026
yrene	-	-	-	-	-	-	-
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Total	0.578	1.351	0.988	0.721	1.367	4.701	1.267

B2. Polycyclic Aromatic Hydrocarbons

PAH	Sample #						
	32	34	35	37	38	39	40
1,6,7-trimethyl-naphthalene	0.040	0.549	0.220	1.212	1.896	15.498	16.291
C1-fluoranthenes & pyrenes	-	0.080	0.034	0.036	0.036	0.182	0.167
C1-phenanthrenes & anthracenes	-	0.401	0.273	2.072	2.575	19.137	15.770
C1-chrysenes	-	-	-	-	-	-	0.052
C1-dibenzothiophenes	-	0.124	0.070	0.649	0.803	5.499	4.778
C1-fluorenes	-	0.186	0.109	1.052	1.339	10.126	11.143
C1-naphthalenes	0.240	0.506	0.383	0.240	0.363	12.663	12.500
C2-phenanthrenes & anthracenes	-	1.059	0.550	1.140	1.410	8.589	6.275
C2-chrysenes	-	-	-	-	-	-	0.065
C2-dibenzothiophenes	-	0.511	0.252	0.759	0.911	4.558	4.043
C2-fluorenes	-	0.725	0.289	1.593	2.010	9.572	9.922
C2-naphthalenes	0.662	1.402	0.909	1.693	3.125	61.084	53.017
C3-phenanthrenes & anthracenes	-	1.105	0.560	0.535	0.605	3.091	2.458
C3-dibenzothiophenes	-	0.575	0.268	0.362	0.383	1.712	1.641
C3-fluorenes	-	0.895	0.407	1.022	1.378	5.316	5.327
C3-naphthalenes	0.259	2.739	1.060	4.693	7.169	66.549	51.553
C4-phenanthrenes & anthracenes	-	0.437	0.199	0.083	0.092	0.580	0.334
C4-naphthalenes	0.068	4.926	1.584	3.761	4.925	31.418	24.538
acenaphthalene	-	-	-	-	-	0.281	-
acenaphthene	-	-	-	-	-	0.211	0.245
anthracene	-	0.025	-	0.041	0.044	0.363	0.226
chrysene	-	-	-	-	-	0.046	0.032
fluoranthene	-	-	-	-	-	0.073	0.049
fluorene	-	0.036	0.038	0.083	0.107	3.332	3.772
naphthalene	-	0.021	-	-	-	0.498	0.469
phenanthrene	-	0.112	-	0.399	0.576	12.558	8.657
pyrene	-	0.057	0.026	0.030	0.023	0.147	0.114
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Total	1.269	16.471	7.231	21.455	29.770	273.083	233.438

B 3. Organochlorines

OC	Samples #						
	1	2	4	5	7	8	10
PCB-total	-	-	-	-	-	-	-
alpha BHC	-	-	-	-	-	-	-
dieldrin	-	-	-	-	-	-	-
gamma BHC	-	-	-	-	-	-	-
p,p'-DDE	-	-	-	-	-	-	-
toxaphene	-	-	-	-	-	-	-
Total	0.000	0.000	0.000	0.000	0.000	0.000	0.000

OC	Samples #						
	11	13	14	16	17	19	20
PCB-total	-	-	-	-	-	-	-
alpha BHC	-	-	-	-	-	-	-
dieldrin	-	-	-	-	-	-	-
gamma BHC	-	-	-	-	-	-	-
p,p'-DDE	-	-	-	-	-	-	-
toxaphene	-	-	-	-	-	-	-
Total	0.000	0.000	0.000	0.000	0.000	0.000	0.000

OC	Samples #						
	22	23	25	26	28	29	31
PCB-total	-	-	-	-	-	-	-
alpha BHC	-	-	-	-	-	-	-
dieldrin	-	-	-	-	-	-	-
gamma BHC	-	-	-	-	-	-	-
p,p'-DDE	-	-	-	-	-	-	-
toxaphene	-	-	-	-	-	-	-
Total	0.000	0.000	0.000	0.000	0.000	0.000	0.000

OC	Samples #						
	32	34	35	37	38	39	40
PCB-total	-	0.028	0.040	0.023	0.104	0.078	0.056
alpha BHC	-	-	-	-	-	0.067	-
dieldrin	-	-	-	-	-	0.044	-
gamma BHC	-	0.028	-	-	-	-	-
p,p'-DDE	-	-	-	-	-	0.023	-
toxaphene	-	0.084	0.053	-	-	0.044	-
Total	0.000	0.140	0.093	0.023	0.104	0.256	0.056

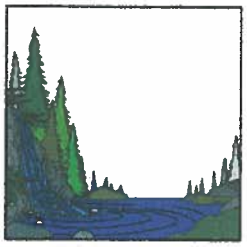
U.S. Fish & Wildlife Service

Ecological Services
Anchorage Field Office

1992 7N02
9270002.1

Technical Report WAES-TR-98-02

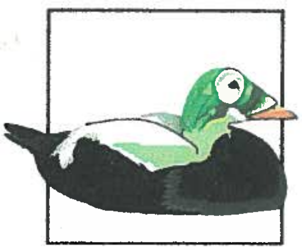
1 of 2
Reports



Habitat Conservation

Contaminants Survey: Island Bay Barrel Cache

Alaska Peninsula / Becharof National Wildlife Refuge



Endangered Species

by:
Sonce de Vries
Mark Giger

Environmental Contaminants

May 1998

Acknowledgments

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Executive Summary

In 1988, the U.S. Fish and Wildlife Service (Service) funded a contaminants project with the following objectives : 1) conduct a reconnaisance-level field inspection of selected, abandoned oil well sites on the Alaska Peninsula and the Becharof National Wildlife Refuge, 2) identify and map abandoned physical remains of oil exploration activities, and 3) collect soil samples for organochlorine, petroleum, and metals analysis.

During the project field survey, several sites warranting further study were identified. One site was a cache of 55-gallon drums found near the mouth of Jute Creek, which flows into Island Bay. The drums were located near an old beach landing area and an access road which parallels Jute Creek.

In early 1990, Refuge Manager Ronald Hood proposed to Exxon officials involved in the *Exxon Valdez* oil spill cleanup that Exxon remove the Island Bay barrel cache and other physical remains of exploration left in the area. A background investigation conducted by Exxon revealed that the barrel cache was not part of past Humble (Exxon) operations. Further investigation identified Mobil as the responsible party. General Petroleum Corporation, a subsidiary of Socony/Mobil (now Mobil), had built a dock and the road to conduct additional oil exploration in the area in the late 1950's. Mobil agreed to remove the barrel cache (USFWS, 1992) and the cleanup occurred in June, 1992. While the barrels were being removed, Service personnel sampled soil and groundwater from the area under and around the site to determine if there was any residual contamination.

A petroleum seep nearby on the banks of Jute Creek was also investigated. It may indicate fuel spillage from equipment refueling during cleanup operations associated with the *Exxon Valdez* spill.

Results of the sampling indicate elevated levels of hydrocarbons. Traces of PCBs and other organochlorines were also found. It is recommended that the sites be investigated further to determine the extent of the contamination and the ecological risk associated with them.

Table of Contents

List of Maps and Tables

Introduction

History and Purpose of the Refuge

Becharof National Wildlife Refuge, located on the Alaska Peninsula in southwestern Alaska (Map1), was created by the Alaska National Interest Lands Conservation Act of 1980 (ANILCA). The purposes of the refuge as described in Section 302(2)(B) of ANILCA include:

(1) to conserve fish and wildlife populations and habitats in their natural diversity including, but not limited to, brown bears, salmon, migratory birds, the Alaska Peninsula caribou herd and marine birds and mammals;

(2) to fulfill the international treaty obligations of the United States with respect to fish, wildlife, and their habitats;

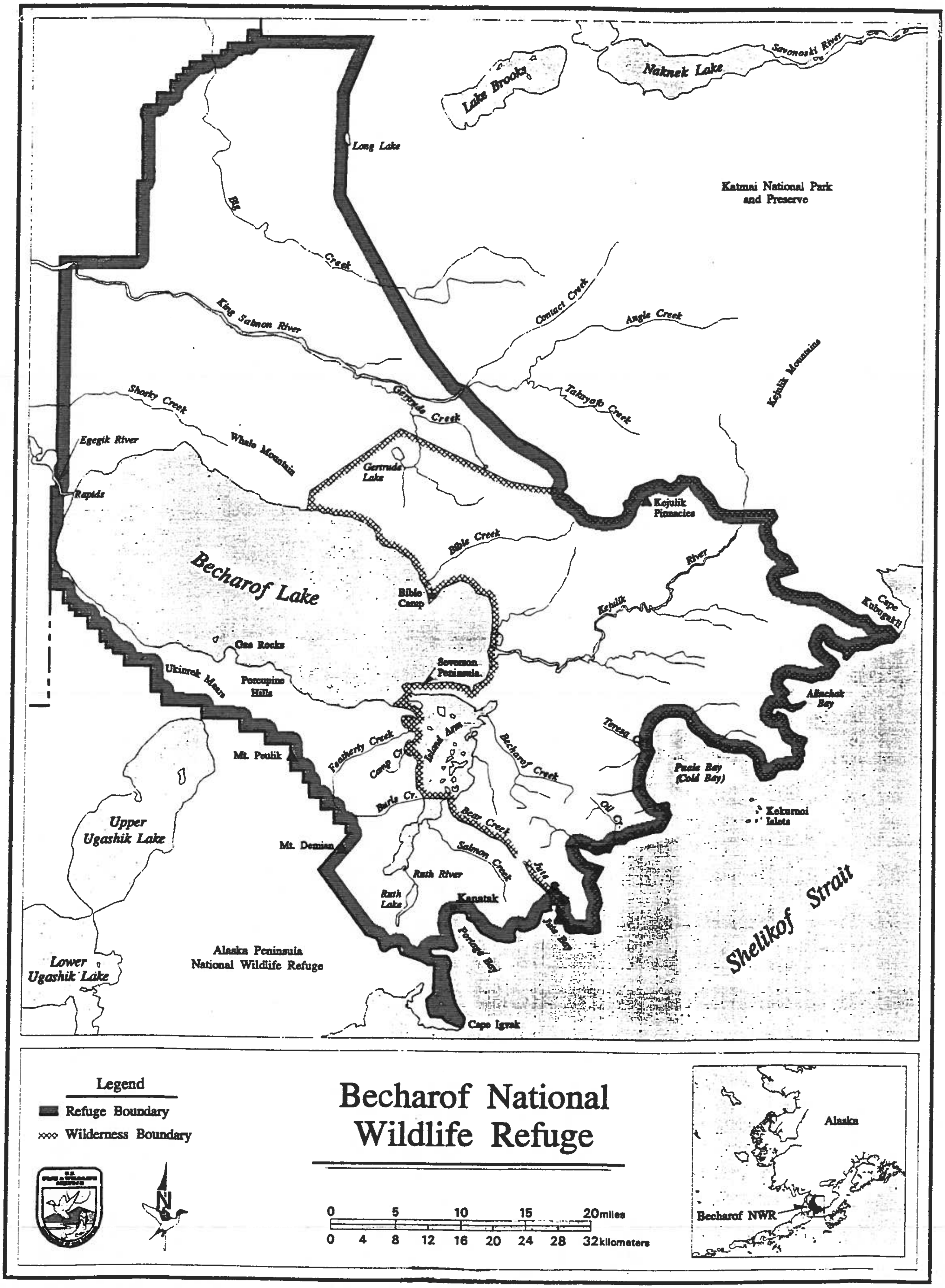
(3) to provide, in a manner consistent with the purposes set forth in subparagraphs (1) and (2), the opportunity for continued subsistence uses by local residents; (and)

(4) to ensure, to the maximum extent practicable and in a manner consistent with the purposes set forth in subparagraph (1), water quality and necessary water quantity within the refuge (USFWS, 1985).

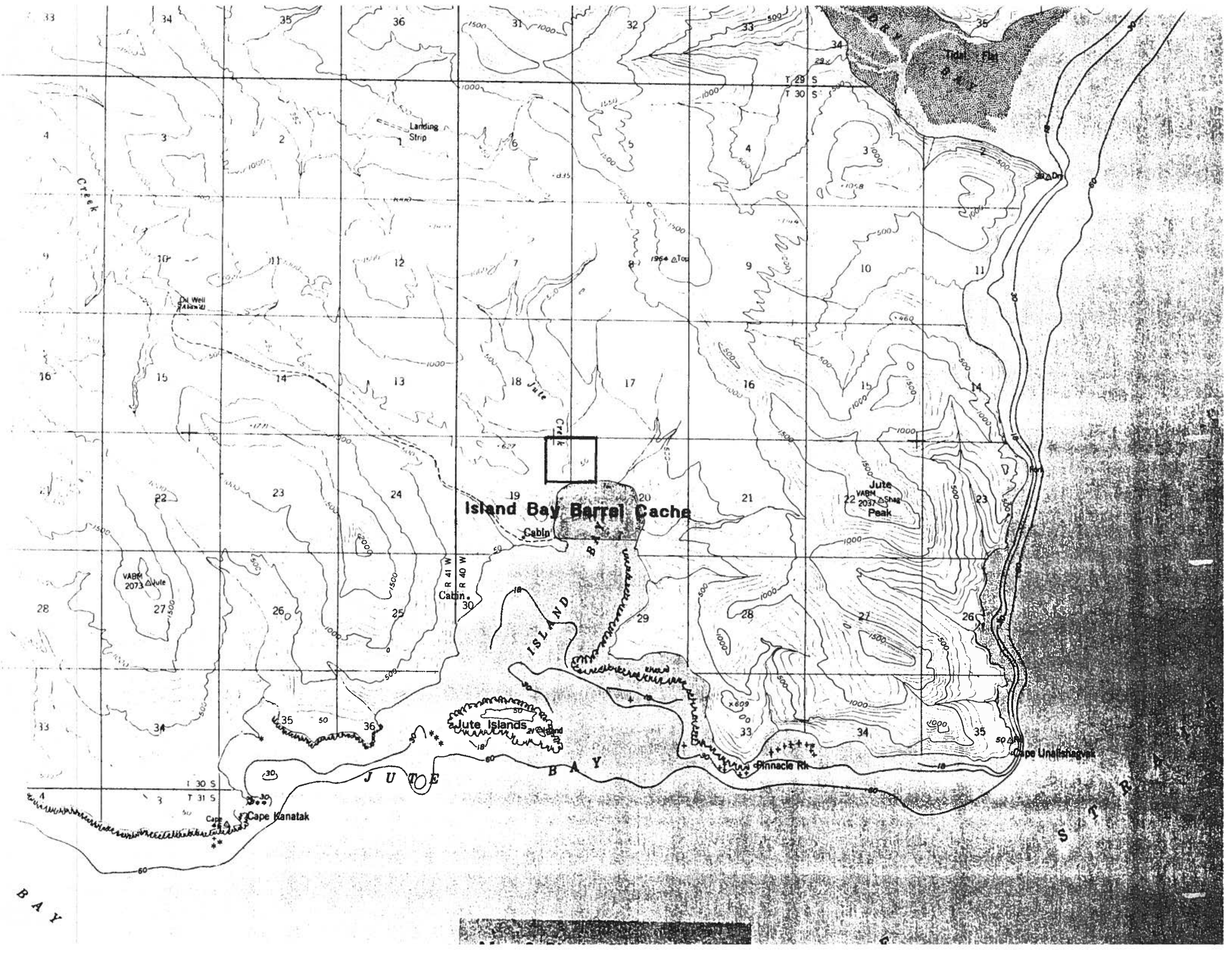
Study Area

Jute Creek and Island Bay are located on the Shelikof Straits-side of the Alaska Peninsula. Jute Creek, which is part of the refuge's southwest wilderness boundary (Map 1), is about two miles long, flows to the southeast and empties into Island Bay, which is an inner bay of Jute Bay (Map 2) on Shelikof Strait.

Jute Creek provides habitat for large numbers of coho (*Oncorhynchus kisutch*) fry (Hood, 1994). Pink *(Oncorhynchus gorbuscha*)and chum (*Oncorhynchus keta*) salmon also utilize Jute Creek for spawning. Brown bears (*Ursus arctos*) depend on the creek for these food sources. Jute Island, at the mouth of Island Bay, provides nesting habitat for hundreds of burrowing tufted puffins (*Fratercula cirrhata*) and, in 1989, an abandoned bald eagle (*Haliaeetus leucocephalus alascenis*) nest was also recorded on the island. An active eagle nest was located near Pinnacle



Becharof National Wildlife Refuge



Island Bay Barrel Cache
Tidal Flat
Landing Strip
Oil Well (Aband)
Creek
Jute Creek
Cabin
Cabin
1964 △Top
VABM 2037 △Shag
Jute Peak
VABM 2073 △Jute
ISLAND BAY
Jute Islands
Pinnacle Rk
Cape Unalishagvak
Cape Kanatak
JUTE BAY
BAY
T 29 S
T 30 S
T 30 S
T 31 S
R 41 W
R 40 W

Point on the mainland to the east (Dewhurst, 1990). Other species that have been observed in the area include: horned puffins (*Fratercula corniculata*), harlequin ducks (*Histrionicus histrionicus*), surf scoters (*Malanitta perspicillata*), black scoters (*Mellanitta nigra americana*), black turnstones (*Arenaria melanocephala)*, rock sandpipers (*Calidris ptilocnemis*), various surfbirds, semipalmated plovers (*Charadrius semipalmatus*), glaucous-winged gulls (*Larus glaucescens*), water pipits (*Anthus spinoletta*), various swallows, red fox (*Vulpes fulva*), and harbor seals (*Phoca vitulina*) (USFWS, 1990).

History of Petroleum Exploration in the Study Area

From 1957 to 1959, a consortium of oil companies composed of the Humble Oil and Refining Company (Humble), now part of Exxon, and the General Petroleum Corporation (now Mobil Oil) conducted an oil and gas exploration program on what is now the Becharof National Wildlife Refuge. A docking installation, which was utilized by both Humble and General Petroleum, was constructed at Island Bay and an access road was built by Humble from Island Bay to service the Bear Creek exploration well near the headwaters of Jute Creek. This exploration well was abandoned in 1959. General Petroleum continued their exploratory program further inland through 1959 but found no commercial quantities of oil and gas. The exploration program was abandoned by 1960. Demobilization was accomplished by General Petroleum through the Bear Creek/Island Bay area.

Study Background

Overflights of the refuge in the 1980s revealed a number of sites where debris from abandoned exploration sites remained. Several sites were visited, including the Island Bay site. Remains of the support facilities and a half-buried cache of drums were found on the banks of Jute Creek where it meets Island Bay. No sampling of the barrels or the immediate area was done at that time.

The refuge, coordinating with the Bureau of Land Management as the regulator of subsurface leasing for oil and gas on federal lands, began requesting Mobil (as the last user of the Island Bay staging area) to submit cleanup plans for the area. Initially Exxon was also asked to remove the Jute Creek barrel cache but they declined since they were convinced that they were not responsible. This assumption rested on the fact that the Department of Interior sent a letter to Exxon in 1960 which stated that "the site was found to be satisfactorily cleaned up at the time of abandonment." It is impossible to know whether the letter refers to the Bear Creek well site, approximately four miles away, or the Island Bay docking faciltity.

In 1992 Mobil offered under the "Take Pride in America" campaign (a U.S. Fish and Wildlife Service initiative to remove debris abandoned on refuges) to remove the barrel cache and miscellaneous metal trash at Island Bay. The cleanup was subcontracted to Northern Exploration Services, who performed the work in 1992.

Potential Impacts from Oil and Gas Exploration

Oil and gas exploration has the potential to contaminate the environment with a variety of chemical compounds. The most probable contaminants are the refined petroleum products utilized to power vehicles and equipment. However, other contaminants such as crude oil, metals and halogenated (ie. chlorinated) compounds may be present due to their use in well drilling and site operations (e.g., drilling mud, batteries for machinery and auxiliary power, maintenance shops, etc.).

Petroleum

Crude oil and refined petroleum products are made up of a complex mixture of chemical compounds. Even when the toxicity of individual compounds is known, it is difficult to determine what the toxic effect of these mixtures will be in the environment due to the additive, synergistic, or antagonistic effects of the various compounds. In addition, crude oil and refined petroleum products can have diverse effects on organisms within the same ecosystem (Overton, et. al., 1994).

The light-end fractions of petroleum hydrocarbons (C6-C10) consisting primarily of benzene, toluene, ethylbenzene and xylenes (BTEX) and napthalene are the most toxic and abundant compounds present during the initial stages of spills or releases. It is in these early stages of a spill that acute toxic effects are most common. As petroleum weathers, these singlering, lower molecular weight compounds, being more volatile, soluble, and/or biodegradable, are lost, leaving behind the less acutely toxic, multi-ring, higher molecular weight compounds known as polycyclic aromatic hydrocarbons (PAHs) (Overton, et. al., 1994).

PAHs are persistent in the environment and have the potential to create chronic toxicity problems. Polycyclic aromatic hydrocarbons are known inducers of cancerous and precancerous lesions (Eisler, 1987), and at least one known human carcinogen, benzo(a)pyrene, has also been identified as a mutagen (Overton, et. al., 1994).

Petroleum products also contain trace amounts of metals including aluminum, nickel, chromium, lead, vanadium and zinc. Although some of these metals are required as essential micronutrients by living systems, they may also become toxic to living systems at relatively low levels of exposure.

Other Contaminants

Halogenated aromatic compounds, such as polychlorinated biphenyls (PCBs), and organochlorine (OCs) compounds, may also be present at older exploration sites. PCBs and a number of OCs (eg. DDT) are no longer manufactured for use in the U.S. but, due to their earlier widespread use and resistance to degradation, they are still found in the environment.

PCBs are closely related to pesticides in their chemical, physical, and toxicological properties. Unlike pesticides, they were never intended to become part of the environment. Most were used in "closed" systems such as electrical transformers and capacitors. PCBs were also used as lubricants, fluids in vacuum pumps and compressors, and in heat transfer and hydraulic fluids. PCBs are mixtures of various isomers and are identified most commonly under the trade name "Aroclor" on the basis of the percent chlorine present. For example, Aroclor 1254, is a mixture of isomers with an average chlorine content of 54 percent by weight. Since there are 209 PCB isomers, and these isomers differ in physical, chemical, and biological properties, evaluation of the potential environmental impacts from a particular PCB product is complicated. PCBs also biomagnify in food chains; and since the late 1960's, they have been linked increasingly to adverse reproductive effects and developmental deficits in a variety of fish-eating birds and mammals (Eisler, 1986).

In some parts of the world, OC-containing pesticides may have been used around exploration sites to reduce disease-carrying insects. The properties that make OCs effective pesticides (low volatility, chemical stability, lipid solubility, slow rates of biotransformation and degradation) also make them a problem for wildlife and humans. Pesticide persistence in the environment and their ability to bioconcentrate and biomagnify within various food chains can result in significant body burdens in some species. In certain cases, such body burdens have been found to be detrimental to reproductive success and even lethal to many species (Ecobichon, 1991).

Objective

The objective of the Island Bay barrel cache survey was to perform post-cleanup sampling of this site in order to determine if contaminants were present at levels that could pose a threat to fish and wildlife on the Refuge.

Site Location

The Island Bay barrel cache is located next to the mouth of Jute Creek adjacent to the wilderness boundary of the Becharof National Wildlife Refuge: Section 20, Township 30 South, Range 40 West, Karluk (C6) Quadrangle (Map 2). The barrels were stacked on timbers and half buried in a foredune area bracketed by an estuary to the northwest and Island Bay to the southeast. The present shoreline is approximately two hundred feet from the site. The soils are unconsolidated beach deposits with a shallow water table under tidal influence. The vegetation includes a few grasses and shrubs.

Methods and Materials

Field Procedures

There were approximately 1500 barrels, many of them labelled as petroleum products, divided into two stacks in the Island Bay barrel cache (see Appendix A for a schematic drawing). Approximately 50 of the barrels contained some residues which were composited into new barrels and removed from the site along with the empty, crushed barrels.

Those containing residues raised concerns that petroleum hydrocarbons may have leaked into groundwater either prior to or during the removal of the barrels. After all the barrels had been removed, one pit each (Pits 1 and 2) was dug in the center of the areas where the two barrel stacks had been located. A hydrocarbon sheen collected on the surface of the groundwater, approximately two feet below ground surface. With visual evidence of contamination, a sampling design was formulated on-site to delineate the impacted area. A total of 12 more pits were excavated and sampled.

In pits 3, 4, and 5, dug between the barrel cache and the estuary, there was no physical evidence of petroleum hydrocarbons at the groundwater table. Pit 6, dug between the barrel cache and Jute Creek to determine if ground water flow was carrying hydrocarbons to the creek, appeared clean. Pit 7, also dug between the cache and creek but farther east, showed a trace of sheen. In pits 8, 9, 10, and 11 which were dug in or near the barrel cache, a light petroleum hydrocarbon sheen was present at the groundwater table. Pits 12, 13 and 14, well removed from the cache, were dug specifically to investigate a petroleum hydrocarbon seep that was evident along the bank of Jute Creek at the edge of the foredune. Pits 12 and 13 were dug beginning where the road crosses the creek and leads to the beach landing area. Although there was no visual sign of contamination on the surface, these pits had a strong hydrocarbon odor and the sand and gravel in them from just below the surface to approximately six feet down was gray and greasy. This apparently was the source of the petroleum seep found further down the beach. Pit 14, dug farthest south, was clean.

The 14 pits were designated and sampled from "clean" to "dirty" based on the visual evidence of petroleum. Two soil samples and one groundwater sample were collected at the groundwater table from each pit, except for pits 13 and 14, from which only two soil samples were collected. In all, 28 soil and 12 groundwater samples were collected for aliphatic hydrocarbons (AH), PAH, and OC analyses.

Samples were collected in pre-cleaned I-Chem 300 Series glass jars which were also used as the sampling scoop. No other sampling tools touched the sample. Surgical gloves were worn by the sampler and were changed between pits. The sample jars were labelled immediately after collection. Samples were transported back to the refuge by helicopter within two hours. The water samples were refrigerated and the soil samples frozen. All were transferred in this condition to Anchorage. Water samples were held refrigerated and soil samples held frozen for two months in Service facilities prior to shipment to the laboratory.

Analytical Procedures

Sample analysis was conducted by the Geochemical & Environmental Research Group, Texas A&M.

Organic and pesticide compounds in soil/ sediment samples were extracted in a Soxhlet extraction apparatus; the extracts were then treated with copper to remove sulfur. They were separated by silica/aluminum column chromatography into the AH, PAH, OC, and PCB fractions and analyzed by gas chromatography.

Organic and pesticide compounds in water samples were extracted using methylene chloride and a separation funnel, concentrated, separated using alumina/silica gel chromatography, and the fractions analyzed by gas chromatography.

Quality Assurance / Quality Control (QA/QC) Screening

The raw data collected during this study was reviewed against the following criteria developed by the Environmental Contaminants Group in the Service's Anchorage Field Office. The criteria are extremely conservative compared to the values generally used by the regulatory community [2x practical quantitation limit (PQL)[1] versus 5x as "significant" values]. The intent is to draw attention to the presence of substances which may present a threat to fish and wildlife.

Analytes which meet the following screening criteria are discussed in the report:

1) Analyte concentrations must be at least 2x the PQL.
2) At least 50% of the duplicates for the analyte must have a relative percent difference <20%,
3) At least 50% of the spike recoveries for the analyte must be within the range of 80-120%
4) At least 50% of the test blanks for the analyte must be non detect.

A complete set of raw data is available in the files at the Anchorage Field Office.

Results and Discussion

Appendix B presents the analytical results for the soil samples from the Island Bay barrel cache. Groundwater samples were non-detect for all analytes.

QA/QC

Table 1 lists the analytes that were tested for in soil samples collected from the Island Bay barrel cache site. A number of the analyte values for AHs and PAHs and most of those for OCs were less than 2x the PQL. A few analytes (n-hexadecane, n-nonadecane,n-octacosane, n-octadecane, biphyenl, and dibenzothiophene) were also eliminated because they did not meet spike or duplicate criteria.

Table 2 lists the sum of the PAH values for all the soil samples collected at Island Bay barrel cache which passed the QA/QC criteria.

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[1]The practical quantitation limit is the lowest level that can be reliably achieved within specified limits of precision and accuracy during routine laboratory operating conditions.

Table 1. Analytes tested for in soil samples collected June 1992 at the Island Bay barrel cache, Alaska Peninsula/Becharof National Wildlife Refuge.

AH	PAH	OC
n-decane	<2x 1,2,5,6-dibenzanthracene	<2x aldrin
n-docosane	<2x 1,2-benzanthracene	<2x hexachlorobenzene
n-dodecane	1,6,7-trimethyl-naphthalene	<2x heptachlor
n-dotriacontane	C1-fluoranthenes & pyrenes	PCB-total
n-eicosane	C1-phenanthrenes & anthracenes	alpha BHC
n-heneicosane	C1-chrysenes	<2x alpha chlordane
n-hentriacontane	C1-dibenzothiophenes	<2x beta BHC
n-heptacosane	C1-fluorenes	<2x cis-nonachlor
n-heptadecane	C1-naphthalenes	<2x delta BHC
n-hexacosane	C2-phenanthrenes & anthracenes	dieldrin
D n-hexadecane	C2-chrysenes	<2x endrin
n-nonacosane	C2-dibenzothiophenes	gamma BHC
D n-nonadecane	C2-fluorenes	<2x gamma chlordane
S n-octacosane	C2-naphthalenes	<2x heptachlor epoxide
D n-octadecane	C3-phenanthrenes & anthracenes	<2x mirex
n-pentacosane	<2x C3-chrysenes	<2x o,p'-DDD
n-pentadecane	C3-dibenzothiophenes	<2x o,p'-DDE
n-tetracosane	C3-fluorenes	<2x o,p'-DDT
n-tetradecane	C3-naphthalenes	<2x oxychlordane
<2x n-tetratriacontane	C4-phenanthrenes & anthracenes	<2x p,p'-DDD
<2x n-triacontane	<2x C4-chrysenes	p,p'-DDE
n-tricosane	C4-naphthalenes	<2x p,p'-DDT
n-tridecane	acenaphthalene	toxaphene
n-tritriacontane	acenaphthene	<2x trans-nonachlor
n-undecane	anthracene	
phytane	<2x benzo(a)pyrene	
	<2x benzo(b)fluoranthene	
	<2x benzo(e)pyrene	
	<2x benzo(g,h,i)perylene	
	<2x benzo(k)fluoranthene	
	S biphenyl	
	chrysene	
	S dibenzothiophene	
	fluoranthene	
	fluorene	
	<2x indeno(1,2,3-cd)pyrene	
	naphthalene	
	<2x perylene	
	phenanthrene	
	pyrene	

<2x Analyte did not meet quality assurance criteria for detection limits.

D Analyte did not meet quality assurance criteria for duplicates.

S Analyte did not meet quality assurance criteria for spike recoveries.

Table 2. Sum of petroleum hydrocarbon concentrations (ppm dry wt.) in soil samples collected at Island Bay barrel cache, Alaska Peninsula/Becharof National Wildlife Refuge.

Sample	Aliphatics	Aromatics	Unresolved Complex Mixture	Total
1	2.952	1.542	29.787	34.281
2	2.484	1.601	24.802	28.887
4	1.748	1.092	15.536	18.376
5	3.005	1.903	25.096	30.004
7	2.763	1.043	25.711	29.517
8	2.755	1.295	26.092	30.142
10	3.622	1.398	32.845	37.865
11	1.609	0.578	12.390	14.577
13	3.609	1.351	33.532	38.492
14	2.469	0.988	18.804	22.261
16	1.517	0.721	14.211	16.449
17	2.666	1.367	22.319	26.352
19	11.288	4.701	44.236	60.225
20	3.252	1.267	21.244	25.763
22	3.680	1.384	34.316	39.380
23	2.666	0.870	23.803	27.339
25	3.985	1.665	36.544	42.194
26	1.903	1.473	15.334	18.710
28	4.537	1.506	40.704	46.747
29	0.439	0.186	8.333	8.958
31	3.687	2.352	30.082	36.121
32	3.532	1.269	29.103	33.904
34	73.080	16.471	407.263	496.814
35	16.601	7.231	95.762	119.594
37	23.399	21.455	98.725	143.579
38	19.752	29.770	73.557	123.079
39	125.845	273.083	480.444	879.372
40	16.282	233.438	56.439	306.159

Organochlorines

Organochlorines were detected in Pit 2 (samples 34, 35), Pit 12 (samples 37, 38), and Pit 13 (samples 39, 40) (see Appendix B3). Concentrations of PCBs (total) were found in all these samples; however, the concentrations are very low (0.028 - 0.104 ppm dry wt.) . Sample 39 contained alpha BHC (0.067 ppm dry wt.), dieldrin (0.044 ppm dry wt.), p, p'-DDE (0.023 ppm dry wt.), and toxaphene (0.044 ppm dry wt.). Gamma BHC at 0.028 ppm dry wt. and toxaphene at 0.084 ppm dry wt. was measured in sample 34 and 0.053 ppm dry wt. of toxaphene were measured in sample 35.

Petroleum Hydrocarbons

Table 2 presents the concentrations of aliphatic, aromatic, and unresolved complex mixtures (hydrocarbon fractions which could not be specifically identified) found in the soil samples. The sum of these compounds for each sample are presented as an estimate of TPH. The assumption is that the true value for TPH would be much higher. The samples from the barrel cache area contained levels generally ranging from approximately 9 to 60 ppm dry wt. of PAHs. Samples 34 - 40 from the barrel cache and from the heavily stained soils close to the creek were significantly higher, containing concentrations ranging from 123 to 879 ppm dry wt.

Samples 34 and 35, taken from Pit 2 in the barrel cache area, indicate that the barrels probably contained petroleum residues and organochlorines which leaked to groundwater. Samples 37 - 40, taken from pits 12 and 13 adjacent to the mouth of Jute Creek where it enters Island Bay, also show elevated levels of petroleum combined with traces of organochlorines. The assumption is made that this is evidence of a spill associated with equipment refueling operations during the *Exxon Valdez* cleanup, particularly when the site is specifically referenced as the only 1990 Exxon helicopter fuel cache in the area (Dewhurst, et al., 1990).

Recommendations

Analysis of the soil samples taken from the barrel cache area and from the assumed spill site at the mouth of Jute Creek indicates that there is some level of PAHs present in all the samples, ranging from a low of 8.958 to 879.372 ppm. Whether these PAHs are normal background or the result of anthropogenic activities cannot be confirmed lacking a control site. However, all physical evidence, plus the presence of organochlorines such as PCBs, alpha and gamma BHC, dieldrin, p,p'DDE, and toxaphene, indicates a strong possibility that petroleum products and other materials have been spilled.

The Service is concerned that these contaminants are already entering ground water, as evidenced by the sheening observed in the sample pits at the barrel cache, and that the apparent spill site at the mouth of Jute Creek is in close proximity to both fresh surface water and the marine environment. It is recommended that the significance of these levels to the fish and wildlife resources in the area be determined through further investigation of the nature and extent of contamination.

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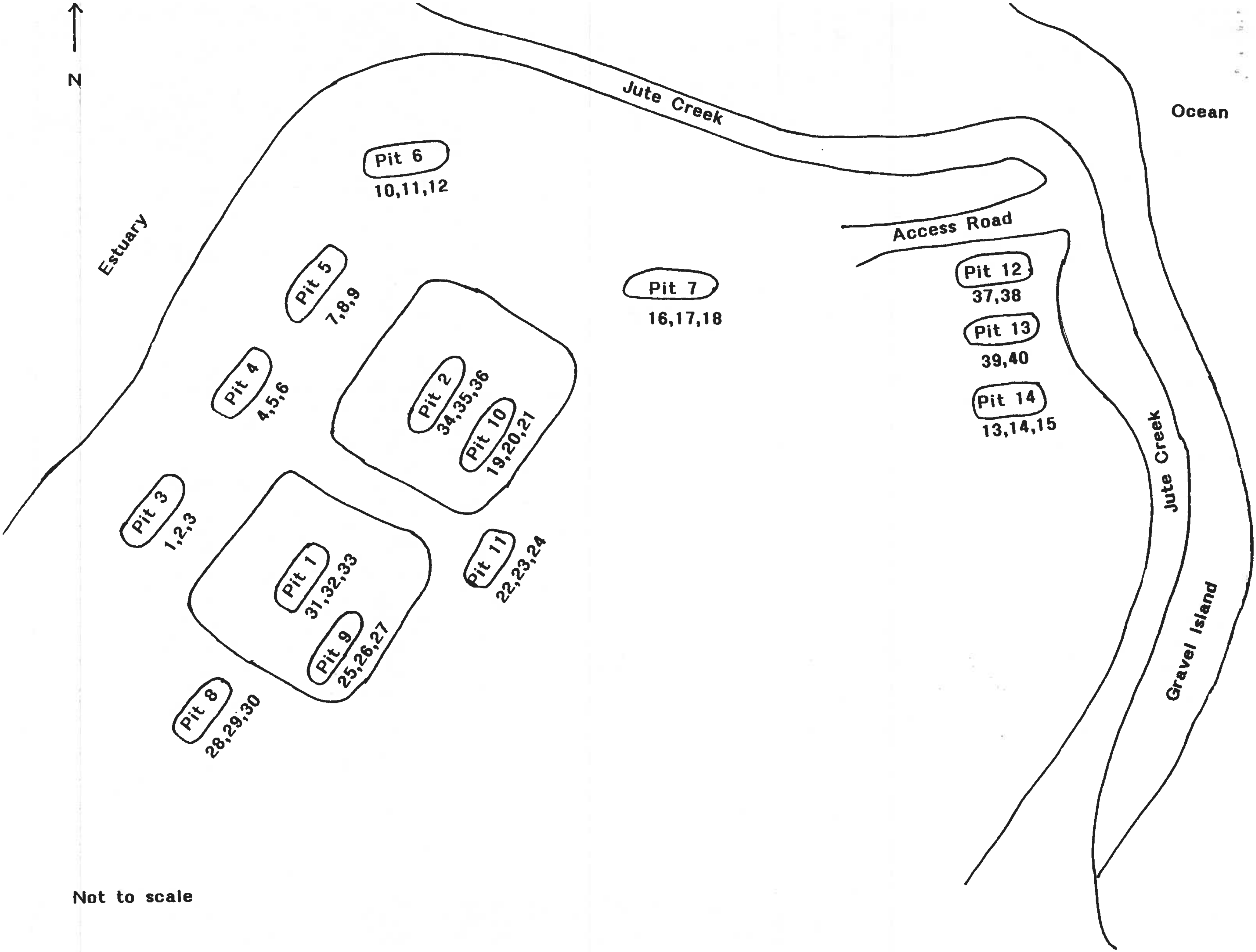
Appendix A

Island Bay Barrel Cache Sampling Sites



ISLAND BAY BARREL CACHE SAMPLING SITES

Appendix B

Contaminants data from the Island Bay Barrel Cache

Concentrations (ppm dry weight)

(-) indicates a concentration <2x the detection limit

B1. Aliphatic Hydrocarbons

AH	Sample #						
	1	2	4	5	7	8	10
n-decane	-	-	0.021	0.033	0.020	-	0.021
n-docosane	-	-	-	-	-	-	-
n-dodecane	0.181	0.135	0.109	0.177	0.222	0.176	0.189
n-dotriacontane	-	-	-	-	-	-	-
n-eicosane	0.020	-	-	0.023	-	-	0.021
n-heneicosane	-	-	-	-	-	-	-
n-hentriacontane	-	-	-	0.020	0.036	0.021	0.021
n-heptacosane	0.029	0.025	0.025	0.040	0.040	0.036	0.034
n-heptadecane	0.043	0.041	0.037	0.061	0.041	0.039	0.062
n-hexacosane	-	-	-	-	-	-	-
n-nonacosane	-	-	-	0.029	0.042	0.029	0.028
n-pentacosane	0.024	0.021	0.022	0.032	0.030	0.026	0.028
n-pentadecane	0.558	0.495	0.322	0.598	0.439	0.481	0.733
n-tetracosane	0.021	0.024	-	0.023	0.021	0.020	0.028
n-tetradecane	1.210	1.004	0.678	1.085	0.984	1.047	1.393
n-tricosane	-	-	-	0.024	0.021	-	0.020
n-tridecane	0.796	0.685	0.486	0.767	0.802	0.826	0.962
n-tritriacontane	-	-	-	-	-	-	-
n-undecane	0.036	0.024	0.027	0.047	0.037	0.027	0.033
phytane	0.034	0.030	0.021	0.046	0.028	0.027	0.049
	-----	-----	-----	-----	-----	-----	-----
Total	2.952	2.484	1.748	3.005	2.763	2.755	3.622

AH	Sample #						
	11	13	14	16	17	19	20
n-decane	0.019	-	-	-	-	-	-
n-docosane	-	-	-	-	-	0.240	0.056
n-dodecane	0.130	0.172	0.118	-	0.173	0.402	0.199
n-dotriacontane	-	-	-	-	-	-	-
n-eicosane	-	-	-	-	-	0.729	-
n-heneicosane	-	-	-	-	-	0.476	-
n-hentriacontane	-	-	0.146	0.025	0.029	0.050	0.043
n-heptacosane	0.034	0.020	0.047	0.025	0.037	0.025	0.025
n-heptadecane	0.031	0.053	0.029	0.028	0.035	1.556	0.341
n-hexacosane	-	-	-	-	-	-	-
n-nonacosane	0.025	0.019	0.121	0.027	0.035	1.000	0.040
n-pentacosane	0.029	-	0.025	-	0.027	0.040	0.021
n-pentadecane	0.267	0.772	0.410	0.323	0.445	2.145	0.662
n-tetracosane	0.021	-	-	-	0.020	0.072	0.030
n-tetradecane	0.547	1.517	0.923	0.629	1.034	2.279	0.978
n-tricosane	0.019	-	-	-	-	0.118	0.032
n-tridecane	0.441	1.018	0.610	0.439	0.784	1.334	0.628
n-tritriacontane	-	-	0.040	-	-	-	-
n-undecane	0.025	-	-	-	0.025	0.051	0.034
phytane	0.021	0.038	-	0.021	0.022	0.771	0.163
	-----	-----	-----	-----	-----	-----	-----
Total	1.609	3.609	2.469	1.517	2.666	11.288	3.252

ϑ1. Aliphatic Hydrocarbons cont...

AH	Sample #						
	22	23	25	26	28	29	31
n-decane	-	-	-	-	-	0.078	-
n-docosane	-	-	-	-	-	-	-
n-dodecane	0.182	0.142	0.144	0.083	0.199	-	0.254
n-dotriacontane	-	-	-	-	-	-	-
n-eicosane	0.028	-	0.021	-	0.023	0.028	0.028
n-heneicosane	0.020	-	-	-	-	0.034	0.018
n-hentriacontane	0.032	0.023	0.023	0.033	0.107	-	-
n-heptacosane	0.032	0.025	0.024	0.029	0.055	0.021	0.024
n-heptadecane	0.067	0.037	0.074	0.028	-	0.049	0.072
n-hexacosane	-	-	-	-	-	-	-
n-nonacosane	0.034	0.023	0.023	0.037	0.106	-	0.021
n-pentacosane	0.025	0.020	0.020	0.025	0.031	0.023	0.025
n-pentadecane	0.782	0.468	0.860	0.343	0.924	0.039	0.662
n-tetracosane	0.028	0.020	0.020	-	0.023	-	0.021
n-tetradecane	1.466	1.115	1.697	0.830	1.782	0.025	1.391
n-tricosane	-	-	-	-	0.021	-	-
n-tridecane	0.905	0.772	1.024	0.495	1.182	-	1.096
n-tritriacontane	-	-	-	-	0.030	-	-
n-undecane	0.024	-	-	-	-	0.056	0.027
phytane	0.055	0.021	0.055	-	0.054	0.086	0.048
	-----	-----	-----	-----	-----	-----	-----
Total	3.680	2.666	3.985	1.903	4.537	0.439	3.687

AH	Sample #						
	32	34	35	37	38	39	40
n-decane	-	-	-	-	-	0.024	-
n-docosane	-	2.352	0.567	0.483	0.355	3.326	0.405
n-dodecane	0.167	0.244	0.077	0.379	0.324	0.966	0.140
n-dotriacontane	-	0.021	-	-	-	-	-
n-eicosane	0.021	7.233	1.657	1.703	1.308	10.319	1.390
n-heneicosane	-	4.585	1.101	0.980	0.729	6.260	0.814
n-hentriacontane	-	0.194	0.020	-	-	-	-
n-heptacosane	0.021	0.109	0.015	-	-	0.111	-
n-heptadecane	0.087	15.054	3.580	4.852	4.016	28.576	3.633
n-hexacosane	-	0.151	0.057	0.022	0.020	0.214	0.019
n-nonacosane	0.019	0.151	0.021	-	-	0.031	-
n-pentacosane	-	0.280	0.066	0.067	0.050	0.428	0.050
n-pentadecane	0.733	17.641	4.041	5.355	4.831	30.912	3.837
n-tetracosane	0.023	0.550	0.119	0.122	0.088	0.749	0.088
n-tetradecane	1.506	11.531	2.485	4.621	3.993	23.697	2.907
n-tricosane	-	1.078	0.260	0.241	0.174	1.512	0.185
n-tridecane	0.894	2.774	0.640	2.218	2.106	6.970	1.217
n-tritriacontane	-	0.043	-	-	-	-	-
n-undecane	0.021	-	-	-	-	0.021	-
phytane	0.040	9.089	1.895	2.356	1.758	11.729	1.597
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Total	3.532	73.080	16.601	23.399	19.752	125.845	16.282

B2. Polycyclic Aromatic Hydrocarbons

PAH	Sample #						
	1	2	4	5	7	8	10
1,6,7-trimethyl-naphthalene	0.068	0.075	0.039	0.070	0.031	0.035	0.034
C1-fluoranthenes & pyrenes	-	-	-	-	-	-	-
C1-phenanthrenes & anthracenes	-	-	0.023	0.033	-	-	0.042
C1-chrysenes	-	-	-	-	-	-	-
C1-dibenzothiophenes	-	-	-	-	-	-	-
C1-fluorenes	-	-	-	-	-	-	-
C1-naphthalenes	0.234	0.234	0.211	0.269	0.241	0.298	0.293
C2-phenanthrenes & anthracenes	-	-	-	-	-	-	0.023
C2-chrysenes	-	-	-	-	-	-	-
C2-dibenzothiophenes	-	-	-	-	-	-	-
C2-fluorenes	-	-	-	-	-	-	-
C2-naphthalenes	0.728	0.745	0.497	0.679	0.520	0.660	0.663
C3-phenanthrenes & anthracenes	-	-	-	-	-	-	-
C3-dibenzothiophenes	-	-	-	-	-	-	-
C3-fluorenes	-	-	-	-	-	-	-
C3-naphthalenes	0.403	0.427	0.234	0.387	0.197	0.240	0.244
C4-phenanthrenes & anthracenes	-	-	-	-	-	-	-
C4-naphthalenes	0.109	0.120	0.067	0.132	0.054	0.062	0.071
acenaphthalene	-	-	-	-	-	-	-
acenaphthene	-	-	-	-	-	-	-
anthracene	-	-	-	-	-	-	-
chrysene	-	-	-	-	-	-	-
fluoranthene	-	-	-	-	-	-	-
fluorene	-	-	-	-	-	-	-
naphthalene	-	-	0.021	-	-	-	-
phenanthrene	-	-	-	0.333	-	-	0.028
pyrene	-	-	-	-	-	-	-
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Total	1.542	1.601	1.092	1.903	1.043	1.295	1.398

B.2. Polycyclic Aromatic Hydrocarbons

PAH	Sample #						
	11	13	14	16	17	19	20
1,6,7-trimethyl-naphthalene	-	0.037	0.021	0.019	0.030	0.176	0.043
C1-fluoranthenes & pyrenes	-	-	-	-	-	-	-
C1-phenanthrenes & anthracenes	-	-	-	-	0.047	0.365	0.053
C1-chrysenes	-	-	-	-	-	-	-
C1-dibenzothiophenes	-	-	-	-	-	0.099	-
C1-fluorenes	-	-	-	-	-	0.101	0.021
C1-naphthalenes	0.135	0.276	0.230	0.154	0.303	0.586	0.231
C2-phenanthrenes & anthracenes	-	-	-	-	0.025	0.212	0.035
C2-chrysenes	-	-	-	-	-	-	-
C2-dibenzothiophenes	-	-	-	-	-	0.098	-
C2-fluorenes	-	-	-	-	-	0.188	0.034
C2-naphthalenes	0.289	0.710	0.506	0.371	0.641	1.188	0.477
C3-phenanthrenes & anthracenes	-	-	-	-	-	0.074	-
C3-dibenzothiophenes	-	-	-	-	-	0.038	-
C3-fluorenes	-	-	-	-	-	0.146	0.028
C3-naphthalenes	0.118	0.260	0.182	0.136	0.228	0.874	0.236
C4-phenanthrenes & anthracenes	-	-	-	-	-	0.020	-
C4-naphthalenes	0.036	0.068	0.049	0.041	0.064	0.323	0.083
acenaphthalene	-	-	-	-	-	-	-
acenaphthene	-	-	-	-	-	-	-
anthracene	-	-	-	-	-	-	-
chrysene	-	-	-	-	-	-	-
fluoranthene	-	-	-	-	-	-	-
fluorene	-	-	-	-	-	0.038	-
naphthalene	-	-	-	-	-	0.025	-
phenanthrene	-	-	-	-	0.029	0.150	0.026
pyrene	-	-	-	-	-	-	-
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Total	0.578	1.351	0.988	0.721	1.367	4.701	1.267

δ 2. Polycyclic Aromatic Hydrocarbons

PAH	Sample #						
	22	23	25	26	28	29	31
1,6,7-trimethyl-naphthalene	0.038	0.030	0.051	0.026	0.061	-	0.041
C1-fluoranthenes & pyrenes	-	-	-	-	-	-	-
C1-phenanthrenes & anthracenes	0.020	-	-	-	-	0.038	0.026
C1-chrysenes	-	-	-	-	-	-	-
C1-dibenzothiophenes	-	-	-	-	-	-	0.994
C1-fluorenes	-	-	-	-	-	-	-
C1-naphthalenes	0.259	0.215	0.313	0.254	0.249	-	0.295
C2-phenanthrenes & anthracenes	-	-	-	-	-	0.038	-
C2-chrysenes	-	-	-	-	-	-	-
C2-dibenzothiophenes	-	-	-	-	-	-	-
C2-fluorenes	-	-	-	-	-	0.028	0.022
C2-naphthalenes	0.684	0.559	0.857	0.840	0.703	0.011	0.617
C3-phenanthrenes & anthracenes	-	-	-	-	-	-	-
C3-dibenzothiophenes	-	-	-	-	-	-	-
C3-fluorenes	-	-	-	-	-	0.028	-
C3-naphthalenes	0.284	0.020	0.367	0.280	0.392	0.014	0.250
C4-phenanthrenes & anthracenes	-	-	-	-	-	-	-
C4-naphthalenes	0.079	0.046	0.057	0.073	0.101	0.029	0.085
acenaphthalene	-	-	-	-	-	-	-
acenaphthene	-	-	-	-	-	-	-
anthracene	-	-	-	-	-	-	-
chrysene	-	-	-	-	-	-	-
fluoranthene	-	-	-	-	-	-	-
fluorene	-	-	-	-	-	-	-
naphthalene	-	-	-	-	-	-	-
phenanthrene	0.020	-	0.020	-	-	-	0.022
pyrene	-	-	-	-	-	-	-
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Total	1.384	0.870	1.665	1.473	1.506	0.186	2.352

B2. Polycyclic Aromatic Hydrocarbons

PAH	Sample #						
	32	34	35	37	38	39	40
1,6,7-trimethyl-naphthalene	0.040	0.549	0.220	1.212	1.896	15.498	16.291
C1-fluoranthenes & pyrenes	-	0.080	0.034	0.036	0.036	0.182	0.167
C1-phenanthrenes & anthracenes	-	0.401	0.273	2.072	2.575	19.137	15.770
C1-chrysenes	-	-	-	-	-	-	0.052
C1-dibenzothiophenes	-	0.124	0.070	0.649	0.803	5.499	4.778
C1-fluorenes	-	0.186	0.109	1.052	1.339	10.126	11.143
C1-naphthalenes	0.240	0.506	0.383	0.240	0.363	12.663	12.500
C2-phenanthrenes & anthracenes	-	1.059	0.550	1.140	1.410	8.589	6.275
C2-chrysenes	-	-	-	-	-	-	0.065
C2-dibenzothiophenes	-	0.511	0.252	0.759	0.911	4.558	4.043
C2-fluorenes	-	0.725	0.289	1.593	2.010	9.572	9.922
C2-naphthalenes	0.662	1.402	0.909	1.693	3.125	61.084	53.017
C3-phenanthrenes & anthracenes	-	1.105	0.560	0.535	0.605	3.091	2.458
C3-dibenzothiophenes	-	0.575	0.268	0.362	0.383	1.712	1.641
C3-fluorenes	-	0.895	0.407	1.022	1.378	5.316	5.327
C3-naphthalenes	0.259	2.739	1.060	4.693	7.169	66.549	51.553
C4-phenanthrenes & anthracenes	-	0.437	0.199	0.083	0.092	0.580	0.334
C4-naphthalenes	0.068	4.926	1.584	3.761	4.925	31.418	24.538
acenaphthalene	-	-	-	-	-	0.281	-
acenaphthene	-	-	-	-	-	0.211	0.245
anthracene	-	0.025	-	0.041	0.044	0.363	0.226
chrysene	-	-	-	-	-	0.046	0.032
fluoranthene	-	-	-	-	-	0.073	0.049
fluorene	-	0.036	0.038	0.083	0.107	3.332	3.772
naphthalene	-	0.021	-	-	-	0.498	0.469
phenanthrene	-	0.112	-	0.399	0.576	12.558	8.657
pyrene	-	0.057	0.026	0.030	0.023	0.147	0.114
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Total	1.269	16.471	7.231	21.455	29.770	273.083	233.438

B3. Organochlorines

OC	Samples #						
	1	2	4	5	7	8	10
PCB-total	-	-	-	-	-	-	-
alpha BHC	-	-	-	-	-	-	-
dieldrin	-	-	-	-	-	-	-
gamma BHC	-	-	-	-	-	-	-
p,p'-DDE	-	-	-	-	-	-	-
toxaphene	-	-	-	-	-	-	-
Total	0.000	0.000	0.000	0.000	0.000	0.000	0.000

OC	Samples #						
	11	13	14	16	17	19	20
PCB-total	-	-	-	-	-	-	-
alpha BHC	-	-	-	-	-	-	-
dieldrin	-	-	-	-	-	-	-
gamma BHC	-	-	-	-	-	-	-
p,p'-DDE	-	-	-	-	-	-	-
toxaphene	-	-	-	-	-	-	-
Total	0.000	0.000	0.000	0.000	0.000	0.000	0.000

OC	Samples #						
	22	23	25	26	28	29	31
PCB-total	-	-	-	-	-	-	-
alpha BHC	-	-	-	-	-	-	-
dieldrin	-	-	-	-	-	-	-
gamma BHC	-	-	-	-	-	-	-
p,p'-DDE	-	-	-	-	-	-	-
toxaphene	-	-	-	-	-	-	-
Total	0.000	0.000	0.000	0.000	0.000	0.000	0.000

OC	Samples #						
	32	34	35	37	38	39	40
PCB-total	-	0.028	0.040	0.023	0.104	0.078	0.056
alpha BHC	-	-	-	-	-	0.067	-
dieldrin	-	-	-	-	-	0.044	-
gamma BHC	-	0.028	-	-	-	-	-
p,p'-DDE	-	-	-	-	-	0.023	-
toxaphene	-	0.084	0.053	-	-	0.044	-
Total	0.000	0.140	0.093	0.023	0.104	0.256	0.056